HDL-SR-77-4

Survey of Codes Employing Nuclear Damage Assessment

HDL-SR-77-4—*Survey of Codes Employing Nuclear Damage Assessment,*
by C. Stuart Kelley

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The study objective was to survey nuclear damage assessment schemes that would be appropriate to tactical nuclear warfare analysis for the Theater Nuclear Force/Survivability (TNF/S) program. The survey asks, "Is there a code (1) suitable for sensitivity studies that seek to improve theater nuclear force survival and (2) that properly utilizes nuclear vulnerability data?" Significant characteristics of surveyed codes were com-

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pared with an "ideal code" that would be appropriate to TNF/S. Attention was given to the specific methodology used for damage calculation and its ultimate utility for sensitivity analyses. Most codes could not be used "off the shelf" because of inappropriate orientation, too high aggregation, or inappropriate methodology for performing sensitivity studies. In addition to obviating the above, the ideal code is modular, calculates nuclear environments individually, and then calculates separately the probability of damage from each environment. Three codes were found to meet the criteria: the first is propietary, the second is unavailable, and the third does not consider enough nuclear environments. Therefore, it was recommended that a code be developed that incorporates the major characteristics of the ideal code. Such a code is presently under development at the Harry Diamond Laboratories.

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TABLES

1. INTRODUCTION

The goal of the survey reported here was to determine whether a nuclear damage assessment routine exists, either as a part of a larger code or by itself, that is suitable for the detailed survivability studies that will be conducted as a part of the Theater Nuclear Force/Survivability (TNF/S) program. The objectives of the TNF/S study are to (1) determine the residual combat capability of the NATO theater nuclear forces in Europe when subjected to the full range of actions and environments that may be encountered both before and after an outbreak of hostilities, with emphasis on the residual nuclear delivery capability; (2) develop feasible alternatives for increasing the nuclear delivery capability and evaluate the relative contribution of the various alternatives; and (3) evaluate the impact of the residual combat capability of the theater nuclear forces on the overall outcome of the conflict, with emphasis on sensitivity of the outcome to the residual nuclear delivery capability.

These survivability studies would form part of a computerized war game. Because nuclear strikes are included in the TNF/S scenarios, a nuclear damage assessment routine is required. The nuclear damage assessment routine selected must, of course, be able to calculate the probability of damage to the NATO theater forces. In addition, it must be able to handle the sensitivity studies that will be performed within the TNF/S program in seeking ways to enhance survival of NATO forces.

The emphasis of the survey was to consider whether such a nuclear damage assessment routine can be plucked "off the shelf" for the needs of TNF/S. If not, can one be so modified or must one be developed?

A significant number of codes, war games, and methodologies exist that exhibit some nominal capability to assess nuclear damage on the battlefield. A number were developed to support the analysis of the extensive damage expected from major exchanges of nuclear weapons. Many codes were designed in support of U.S. targeting doctrine and weapons development and hence treat mainly radiation casualties. Finally, a number of codes were developed with simplified damage assessment routines to support larger war-gaming applications.

During the survey, existing codes were reviewed only with respect to the adequacy of their nuclear damage assessment routines so as to eliminate unacceptable codes. A detailed technical analysis of codes selected for TNF/S is greatly simplified by our reduction of the number of codes to be considered. This survey is not intended to explore the accuracy of the internal technical calculations. It does emphasize the input/output (I/O) characteristics and the processing algorithms of these routines. The specific categories that were treated in detail

were target and weapon deployment, nuclear environments, use of target vulnerability data, specific damage calculation techniques, and the output capabilities.

Currently, a variety of techniques exists for calculating nuclear damage. They rely on different methodologies and can give quite different results when applied to the same problem. In addition, one of the methodologies (AP-550, see sect. 6) is not appropriate to sensitivity studies. Accordingly, the calculational methodology and its associated data base are strongly emphasized.

In addition to evaluating codes that are appropriate to the needs of TNF/S, the survey can serve as a state-of-the-art review of the current capabilities in the area of nuclear damage assessment. It can also be used to identify nuclear damage assessment routines that are appropriate as subsystems of larger war-game codes or as independent analytical tools. For these reasons, the survey also considers the degree to which a routine is made modular. The attributes and the deficiencies of the various codes are indicated here by their comparison with the attributes of a conceptual "ideal code" that would be eminently suitable for use in TNF/S, or for use by itself, or capable of coupling to other codes. This ideal code also serves as a baseline against which we can compare and evaluate candidate codes.

According to R. Epperson of the Defense Communications Agency (DCA), another survey of codes that has an emphasis different from that reported here is being performed by DCA. They currently emphasize strategic codes, but soon will be dealing with tactical codes. These DCA studies emphasize communications equipment. The RDA Corporation, Santa Monica, CA, has performed a survey of combat codes, both conventional and nuclear (J. Esser, RDA, 1976). The emphasis of that survey was distinct from that presented here in that RDA looked only at high levels of aggregation. The finest resolution dealt with by the survey was a battalion of tanks versus an infantry brigade. The codes surveyed looked only at major effects, were highly aggregated (mostly theater level) and used "cookie-cutter" methodology. (Items are "killed" inside a certain radius from burst; "alive" outside it.) As will be discussed in section 5, such characteristics are not appropriate to the needs of TNF/S. The RDA survey and this survey do, however, complement each other, and together contain good cross sections of nuclear damage codes and representative analytical techniques.

Our goal was not to review in detail the accuracy of the technical methodologies used within the tactical codes (for example, the algorithms for the nuclear environments, those for the damage calculations, and those for other calculations that use equations to describe such phenomenology as weapon CEP (circular error probable) as a function of missile range). The aim was to select those codes that are relevant to TNF/S, and thus reduce in number the codes requiring such detailed examination prior to use by TNF/S.

2. SURVEY PROCEDURE

Basically, there were three phases in this survey of existing codes that employ nuclear damage assessment. The first phase was to try to identify all codes that contained nuclear damage assessment, the second phase was to compile sufficient information concerning these codes to evaluate the codes in view of TNF/S needs, the third was to perform this evaluation. In this section, we describe the methods employed in the first phase of the analysis, that of identifying codes that employ nuclear damage assessment.

The task of identifying codes relevant to the needs of TNF/S began with a list of six codes that were believed to contain nuclear damage assessment routines. This list was compiled from informal discussions at the Harry Diamond Laboratories (HDL) and provided a starting point for the study. This basic list was doubled as a result of informal discussions during one of the TNF/S Lead Element meetings.

At this point in the survey, it was decided that sufficient information was available to prepare a survey questionnaire (described in sect. 3), tailored to identify the attributes--both positive and negative--of each code, and answerable by telephone or from documentation on each code.

Each organization that was believed to be most intimately concerned with a particular code was contacted and asked for information. Several questions were presented: (1) Who is the best technical person to contact regarding the nuclear damage assessment portion of the code? (2) What relevant technical documentation exists concerning this portion of the code? (3) What other codes do you know of that contain nuclear damage assessment, and who should be contacted? (4) Do you know of existing bibliographies of such codes, of their titles, and of their abstracts? (5) Would you answer these specific questions from the survey questionnaire?

This format assisted in completing the survey questionnaire, identifying new codes, and identifying new sources of information. Each lead on a new code or procedure to find new codes (e.g., the mention of a bibliography) was followed up, and for each new contact the same procedure was followed. This procedure continued until no new codes surfaced, no new personal contacts were identified, and no new sources of information were mentioned.

The requested documents provided three types of information: (1) specific technical details concerning the code in question, (2) references to other existing codes, and (3) references to bibliographies. All such leads followed the same procedure.

In addition to personal contacts and referenced documents, three bibliographies of relevant codes were identified.[1-3] Two originated with the U.S. Army Concepts Analysis Agency (CAA), and the third with the Studies, Analysis, and Gaming Agency (SAGA).

A literature search was made through the Defense Documentation Center (DDC) for nuclear damage assessment routines using key words thought to characterize codes in which such routines would be used. Attention was centered on tactical nuclear warfare games that employed nuclear weapons.

The resulting list of candidate codes and brief descriptions of these codes are presented in appendix A. That appendix presents the codes (and their descriptions) in alphabetical order by acronym and also lists in alphabetical order the organizations that have the expertise to answer technical questions concerning specific codes.

At this point in the survey, the codes that employ nuclear damage assessment could be considered to have been identified, and the technical points of contact for the codes located. What remained was to actually perform the survey and assess the results.

3. THE SURVEY QUESTIONNAIRE

The survey questionnaire was designed primarily to address questions relevant to TNF/S. Although the survey was to be oriented towards the needs of TNF/S, we knew that the survey could simultaneously serve as a basis for comparison of the numerous codes and thereby provide a survey of the state of the art in nuclear damage assessment. In fact, part of section 7 of this report presents a matrix involving the nine most relevant codes (and also the "ideal code" discussed in sect. 5) and the "scores" of these codes for a particular survey question.

Several specific areas were deemed worthy of being addressed in some detail by the survey. These are listed below in the order of the importance assigned to each.

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[1] *U.S. Concepts Analysis Agency, Tabulation of Models of Interest to CAA, Bethesda, MD (July 1976).*

[2] *U.S. Concepts Analysis Agency, Abstracts of Studies, Bethesda, MD (January 1976).*

[3] *Harry J. Walther, Catalog of War Gaming and Military Simulation Models, 6th ed., Studies, Analysis, and Gaming Agency (SAGA) 236-75 (June 1975), AD 012803.*

Time Dependence.--Because the ultimate code selected (or developed) will be used for sensitivity studies, the question of time dependences (e.g., target motion) must be addressed. Also, the output of the code will be uncertain to the extent that the input data are uncertain and also to the extent that statistical uncertainties occur in the actual calculations within the code. For example, the output could be affected by using a Monte Carlo approach to weapon CEP to relate weapon actual ground zero (AGZ) to its designated ground zero (DGZ). The code should be able to distinguish between output uncertainties that are due to data uncertainties and those due to processing uncertainties. Otherwise, meaningful trends in the output cannot be tracked with certainty.

Subdivision of Area Targets.--The codes treat area and point targets differently in the nuclear damage assessment routines. Usually, an area target is subdivided into smaller and smaller subtargets until the subtargets can be effectively considered to be point targets. The criteria used to distinguish between area and point targets may vary from code to code, and the output of the code may vary accordingly. It was therefore advisable to ascertain each code's capability for subdividing area targets. Also considered was how such area targets were aggregated into larger, single-identity targets. Some codes were found to be unable to collocate personnel and equipment. If the code is not able to collocate people and equipment, the actual outcome of a battle could be contrary to predicted outcome. Communication links might present a critical example of this characteristic.

User Specifications.--The candidate codes should permit the user to specify the weapon laydown and to be able to specify multiple weapon bursts and various heights of burst (HOB's). A weapons allocation routine, however, could be useful in future applications of the TNF/S code and could circumvent the need for a user to input the laydown.

Two aspects of each nuclear damage assessment routine in each candidate code were (1) how it handles the calculation of each of the environments (blast, initial nuclear radiation, electromagnetic pulse (EMP), etc.) from a nuclear burst, and (2) whether the routine makes proper use of target vulnerability in the damage calculations and, in fact, whether proper vulnerability data are input to the routine.

Format.--The format of the routine was also considered important. Can the output of the code group the damage by burst number and by that environment which is primarily responsible for the damage? This question would be critical for future sensitivity studies. Is the nuclear damage assessment routine modular in the sense that it could be readily integrated into an alternative, already-existing war game? Has the routine been independently assessed?

Other Attributes.--In addition to the above areas of interest, many routines were found to have specific, useful attributes that, although not of prime interest to TNF/S, do present capabilities that would be useful in other applications. The questionnaire sought to flag such useful attributes. These are listed in appendix B. Table I lists the categories and specific question areas of the questionnaire. As indicated in section 2, the questionnaires were completed using statements from code users, originators, and assessors of the codes, as well as from existing documents that describe the codes.

TABLE I. SUBJECT AREAS OF THE SURVEY QUESTIONNAIRE

Nuclear hit			
Target description	Target location and deployment	Weapon description and delivery accuracy	
Multiple targets Target size, shape, orientation Number of target elements, their resolution Personnel location, shielding Equipment by type, criticality Communication links	Target location, how distributed Target movement vector Relation of detected element to rest of target	Multiple weapons Avoid multiple kill volume Weapon yield, range, HOB, CEP DGZ selection, weapon reliability Variability due to scenario changes	
Nuclear kill			
Environment	Equipment vulnerability	Personnel vulnerability	Mathematical approach
Blast, total dose, neutron, γ, thermal, EMP Weather (re thermal), terrain Environment specification flexibility (by weapon type versus yield)	Blast, neutron, γ, EMP, thermal Level of damage, time to repair	Blast, total dose, thermal Postures, flexibility, time dependence Multiple bursts for dose Bin personnel by dose	Data source, guideline algorithm Cookie cutter or probabilistic Monte Carlo or deterministic Uncertainties in all categories Edit capability (by burst number, damage cause) Target/weapon overlap - how Computer + language, proprietary code, modular code Independent assessment of code Output: Subroutine, final

At this point in reporting the survey, it may be considered that the questionnaires have been completed and the analysis of the results remains to be done.

4. FIRST-ROUND SELECTION

Over 40 codes from over 20 organizations were identified as potential candidates (see app A). These codes were thought to deal with

or include nuclear capabilities. The list is certainly not all-inclusive of codes containing nuclear-oriented subroutines, but is considered comprehensive as regards the specific needs of TNF/S.

Now a first-round selection was made from the list in order to eliminate those codes that are not relevant to the needs of TNF/S. Although a given code may not pass the initial round of selection, any positive attributes this code possesses that are relevant to TNF/S needs, or the needs of any ultimate nuclear damage assessment routine, are flagged and compiled in appendix B. Of course, such positive attributes of a noneliminated code will also be flagged and presented in appendix B.

The first-round selection consisted of retaining candidate codes on the basis of the criteria in the following list. Obvious first-round selection criteria are these: Is the code nuclear; is it oriented to tactical warfare; is the code now available; is this the most recent version; is it known to be free of basic flaws; does it output distributions of damage necessary for TNF/S? Another criterion is whether the code is relevant to the needs of TNF/S. For example, a code that turns out to be a nuclear fallout model for war games is not especially relevant to the tactical scenarios anticipated for TNF/S. Nevertheless, such a code would be flagged as having a useful attribute that might be relevant to future war-game efforts. In fact, it would be convenient if the TNF/S code were capable of coupling to a fallout model.

The final first-round selection criteria concerned the level of aggregation of targets within each model. From the standpoint of physical vulnerability, the resolution of battlefield items must be at or below the company level--the platoon level is preferable. The reason for this is that for large-area battlefield targets, the damage caused by a nuclear burst can vary significantly across the target. Thus, for these targets, damage cannot be specified by the value of a single parameter alone. By their very nature, a number of codes that examine theater warfare do not possess a sufficiently low level of aggregation. Aggregation at the battalion level is common for such codes. In carrying out nuclear damage calculations, the ultimate TNF/S code will deal with the effect of a specific weapon on a given battlefield item. The vulnerability data that will be used in such a calculation are often presented for such items as radios, people, and trucks. On the other hand, a given model was not excluded because it dealt with low levels of aggregation. It must be recognized, however, that such models may require aggregation schemes in order to be appropriate to theater situations.

Table II lists codes that were examined and that did not pass the first-round selection criteria (see also app A). Included in that table are the specific reasons why each code is excluded from further

TABLE II. CODES REJECTED DURING FIRST-ROUND SELECTION

Code	Reason rejected
ATLAS	uses AP-550, too highly aggregated (NUFAM output is its input), undergoing revision
BARBAROSA	scenario selection model
CASM	under development (4 years off) at SAGA
CATTS/MAFIA	too highly aggregated (does not subdivide battalions)
COMBAT-II	too highly aggregated (company and above vulnerability levels)
DACOMP	offensive aim point selection code
DEMS	outdated, undocumented, unused
DIVWAG	too highly aggregated (division level and above)
FORCAST-2	deals only with structures and collateral damage
JEREMIAH	not nuclear
LACOMP	solely a fallout model
LULEJIAN-I	not nuclear
MCNUKEN	research tool for constructing tactical, nuclear models
MINTSIM	in development to correct basic flaws and to increase aggregation
NAR	part of NUFAM
NDAM	strategic model
NUCAMMORATES	computes ammunition consumption rates
NUCWAL	allocation program for strategic scenarios
NUDAS	currently a one-on-one research tool
QTEM	too highly aggregated (corps-level fire fighting; but subdivision to launcher level is possible) uses AP-550
RADSUM	strategic model
RAM	not nuclear
RAPIER	deals only with collateral damage
SATAN	highly aggregated (nuclear damage is done by TANDEM)
SCORES NUCLEAR EXCURSION	too highly aggregated (down to company level with difficulty)
SEER-III	fallout model
SIDAC	only strategic; TANDEM replaces it
SNAP	only strategic
SPHINX	too highly aggregated (brigade level and above)
STANCE-78	too highly aggregated (corps level and above)
TALLEY/TOTEM	not nuclear
TARTARUS	too highly aggregated (battalion level and above)
UNICORN	highly aggregated force allocation code
UNNAMED LULEJIAN MODEL	too highly aggregated (battalion level and above)
UNNAMED HEADQUARTERS EUCOM MODEL	to become tactical nuclear model requires DOSDIS as subroutine

consideration. As can be seen from table II, the most common reasons for deletion involve aggregation levels and relevance to TNF/S. These codes are briefly described in appendix A.

Table III lists the nine codes that passed the first-round selection. This table also lists the organizations considered to be the technical proponents of these codes and the key technical people who appear to be best versed in the technical details of the codes. These nine codes are described in more detail in appendix C.

TABLE III. CODES RELEVANT TO TNF/S AFTER FIRST-ROUND SELECTION

Code	Proponent	Contact
Brigade Survivability*	Scientific Applications, Inc. (SAI)	W. Schilling, SAI, 703-821-4300, McLean, VA
DOSDIS*	Stanford Research Institute (SRI)	P. Dolan, SRI, 415-326-6200, x3558, Menlo Park, CA
DWEEPS	Lawrence Livermore Laboratory (L^3)	R. Gard, L^3, 415-447-1100, x7621, Livermore, CA
LADCAR	Los Alamos Scientific Laboratories (LASL)	T. W. Dowler, LASL, 505-667-4335, Los Alamos, NM
LANDEM	LASL	T. W. Dowler, LASL, 505-667-4335, Los Alamos, NM
NONAME	SAI	R. Sumner, SAI, 703-821-4518, McLean, VA
NUFAM	Concepts Analysis Agency (CAA)	E. Smith, CAA, 301-295-1681, Bethesda, MD
TACNUC	Institute of Defense Analysis (IDA)	E. Kerlin, IDA, 703-558-1323, Arlington, VA
TANDEM*	Rand/SAI	M. Drake, SAI, 714-459-0211, La Jolla, CA

**These codes are currently controlled by the Defense Nuclear Agency (DNA). For technical information, contact the Vulnerability Directorate of DNA before contacting individuals listed.*

The Brigade Survivability code (alternatively known as Combat System Survivability Model), DOSDIS, and TANDEM are currently under the auspices of the Defense Nuclear Agency (Vulnerability Directorate). Accordingly, this Directorate should be contacted before information is requested about those codes from the technical personnel listed in table III.

At this point in the survey, the nine codes of table III were found to be appropriate to the scope of TNF/S and also to contain nuclear damage assessment routines that could be appropriate to other studies. The remaining analyses consist of examining the specific details of these routines and comparing them against a standard that is developed in the following section in order to select the most appropriate routines.

5. FEATURES OF THE IDEAL CODE

This section is devoted to the specific characteristics of an ideal nuclear damage assessment routine that can serve as a benchmark against which to compare the nine relevant codes selected (sect. 4). This code is ideal in the sense that it is minimally acceptable both to the needs of TNF/S and to the needs of any routine that calculates nuclear damage. Additionally, the ideal code would couple well (with minimal changes) to existing codes that either serve as its input or use its output.

The ideal code is conveniently subdivided into five subroutines: targets, weapons, environment, target vulnerability, and the calculational procedure. Each subroutine contains both primary and secondary attributes. Primary attributes refer to those qualities that are needed by a nuclear damage assessment routine, while secondary attributes are those that would be convenient to add at a later date to enhance the current applicability of the routine. Appendix B lists "tertiary" attributes that are expected to be needed in future war-game modeling efforts. Tables IV through VI give the primary and secondary attributes desired for the ideal code. Primary attributes are those that can be easily incorporated into the ideal code; secondary attributes are those that would require about one year's effort to update a code possessing solely the primary attributes.

Table IV describes the target portion of the routine along the lines of input requirements to the code, as well as suggesting the internal calculations that are required of the code. For example, the ability to aggregate platoon-sized targets into larger-resolution targets places restrictions on the input to the routine (where platoons aggregate in a nonuniform fashion, input must be at the platoon level). Also restricted are the calculations that are to be based on the description of the target (the routine must decide when aggregates of platoons can be treated as point targets and when the platoons themselves can be treated as point targets).

Table V includes the categories of weapons, environments, and target vulnerabilities. The characteristics listed in this table may be considered to operate on the description of the target, as given by table IV. Using the scenario specified by table IV, the appropriate

TABLE IV. FEATURES OF THE IDEAL CODE: TARGETS

Subroutine category	Attributes	
	Primary	Secondary
Targets	Area and point targets located by longitude and latitude. Target shape specified by convenient geometrical figures. Subdivide targets down to platoon size where necessary. Platoon treated as area target whose internal distribution of value is uniform. Subunits aggregated into larger units whose internal distribution of value and spacings can be specified. Personnel grids and equipment grids can overlap, but need not coincide. Platoon composed of various equipment types and personnel in varying postures. Motion vectors specified for point and area targets. Offset DGZ from target centroid, as target acquisition does not locate target centroid. Target location and decomposition into subtargets accompanied by target acquisition time.	Uncertainties (CEP fashion) in target location and motion vector. Target orientation. Terrain effects on deployment and weapon environment.

nuclear weapons (including such weapon variations as enhanced radiation --ER--type) are selected and described in table V with sufficient detail to permit the calculation of damage to these targets. The weapons characteristics may be input by the user, or (at a later stage) be target allocated by a weapons allocation subroutine. With the specification of the weapons to be used in the laydown, it is then possible to calculate the intensity of each nuclear environment as a function of distance from the AGZ's of the weapon. Many codes perform

TABLE V. FEATURES OF THE IDEAL CODE: WEAPONS, ENVIRONMENTS, TARGET VULNERABILITIES

Subroutine category	Attributes	
	Primary	Secondary
Weapons	User-selection laydown. Yield, HOB, CEP, reliability weapon peculiarites (ER). Range- and weapon-dependent CEP. User flexibility in CEP choice. AGZ differs from DGZ.	Weapon specified by type, or by closest match to existing weapons.
Environment	Specify environment versus distance from AGZ for: blast, thermal (include weather factors), total dose, neutron, $\dot{\gamma}$, EMP.	Uncertainties in specification of environment.
Target vulnerability	User-established criteria. Input is probability of damage (prompt [illegible] delayed casualty for levels of damage versus intensity of environment for: blast, thermal, total radiation dose, $\dot{\gamma}$, neutron, EMP; for each shielding factor.	Total dose is sum over number of detonations. Time to repair lightly damaged units.

these calculations with considerable detail (read complexity) and presumed accuracy. It is probably more desirable, however, to employ a series of simple algorithms that give each environment intensity as a function of distance from the burst with an acceptable degree of accuracy once the weapons characteristics are given.[4]

The target vulnerability (table V) portion of the routine is basically contained in the input to the code and can be specified simultaneously with the target data if desired. The data can be of the form[5] that specifies various damage categories resulting from nuclear environments, or can be of the form of two parameters that specify the

[4] *W. E. Sweeney, Jr., C. Moazed, and J. Wicklund, Nuclear Weapons Environments for Vulnerability Assessments to Support Tactical Nuclear Warfare Studies, Harry Diamond Laboratories TM-77-4 (June 1977).*

[5] *Department of the Army, Staff Officers' Field Manual, Nuclear Weapon Employment (U), Field Manual 101-31-2 (February 1963). (SECRET)*

TABLE VI. FEATURES OF THE IDEAL CODE: CALCULATIONAL PROCEDURE

Attributes	
Primary	Secondary
Output is probability of damage for each level of damage and each equipment type	Parallel runs performed simultaneously in sensitivity studies
Damage and its extent to be sorted by burst and <u>cause</u>	Two sets of error bars per calculation: (1) uncertainties in data; (2) statistical nature of calculation
Multiple kills avoided: remove inactive units at each detonation	User option to request damage at any unit size (up to theater size)
Does not use cookie-cutter procedure	Nuclear-created obstacles flagged for deployment consideration
Code should be independently assessed	User reallocates weapon laydown at each detonation (interactive)
	Facility to interact with a standard fallout model
	Use of common computer and language

damage probability versus environment intensity curve for the item of interest.[6-8] At any rate, the vulnerability data must include all important damage-causing environments.

The calculational procedure (table VI) basically consists of putting together the environment that a target experiences and the target's vulnerability to calculate the probability of damage suffered by that target. One of the major output capabilities of the nuclear damage assessment routine is that it can collate the battlefield damage in any fashion specified by the user (as examples, by environment or by burst number).

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[6] *W. E. Sweeney, Jr., A Vulnerability Array for Tactical Nuclear Warfare Studies, Proceedings of the 37th MORS Symposium (Military Operations Research Society), Alexandria, VA (June 1976).*

[7] *W. L. Vault and W. E. Sweeney, Jr., The Vulnerability Data Array, American Defense Preparedness Association Vulnerability/Survivability Proceedings (October 1976).*

[8] *K. LePoer, EMP Survival Profiles for Tactical Equipment, American Defense Preparedness Association Vulnerability/Survivability Proceedings (October 1976).*

Figure 1 shows the basic flow scheme for the nuclear damage assessment routine. Composing the routine of separate modules is useful both for debugging and for future applications of the routine either as a subsection of a larger code or as a damage assessment routine by itself.

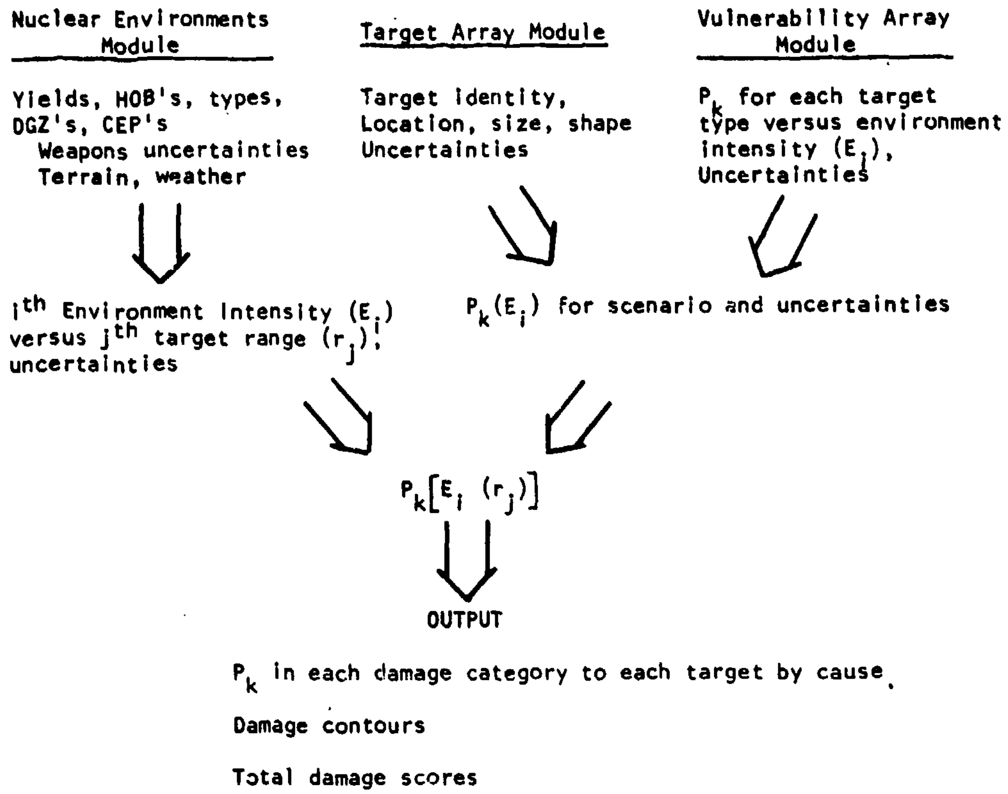

Figure 1. The basic flow scheme of the ideal nuclear damage assessment routine.

We are now in a position to compare the attributes of the ideal code to those of the nine codes in contention (sect. 4) in order to determine by stringent selection criteria (sect. 6) which of these nine codes are appropriate to the needs of TNF/S and the needs of an independent nuclear damage assessment routine.

6. STRINGENT SELECTION CRITERIA

This section sets forth stringent selection criteria that are relevant to the performance of the nuclear damage assessment routine to be applied to the TNF/S analyses. In section 7 these criteria are applied to the nine codes that survived the first round of selection.

The primary emphasis is on I/O characteristics of the routines and their processing, especially in regard to the proper use of vulnerability data and the applicability of the output to sensitivity studies. The specific criteria are listed in table VII. The scenarios, weapons, environments, and vulnerabilities all come under the heading of input, whereas the output consists of the probability of damage, as described earlier (sect. 5). The processing is concerned with the method used by each code to obtain the probability of damage (see below). As is discussed in section 7, the main downfall of five of the nine codes lies with the methods by which they calculate the probability of damage to a target. Accordingly, some detail is provided here concerning the various methodologies for calculation of damage probabilities.

TABLE VII. STRINGENT SELECTION CRITERIA

Scenario input	Weapon input	Environment†	Vulnerability input	Output
*(1) Units readily subdivided to platoon size (2) Personnel and equipment grids overlap (3) Platoons can contain several equipment types and several personnel postures.	(4) User selects laydown and weapon characteristics	(5) Blast (6) Thermal (7) Total dose (8) Neutron (9) EMP (10) $\dot{\gamma}$	(11) Curves of probability of damage versus environment intensity at each damage level and for each shielding	(12) Probability of damage for user-specified unit size at each level of damage for each type of equipment by burst number and cause. (13) Is the code now available? User's comments

*Numbers are referenced in table XI.
†Either inputs or calculates intensity versus distance for (5) through (10).

There are currently two commonly used target damage methodologies. The first is referred to as dash two (because it is taken from the field manual FM 101-31-2)[5] that was developed by the Army Nuclear Agency and intended for tactical uses. Its data base is primarily the DNA Effects Manual No. 1 (EM-1).[9] The second analysis methodology, commonly referred to as AP-550, was developed by the Defense Intelligence Agency (DIA) for strategic targeting.[10] It has been found that, given the same scenario and weapon laydown, the two methodologies do not always produce the same damage probabilities and, on occasion, have been found to give widely varying results.*

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[5] *Department of the Army, Staff Officers' Field Manual, Nuclear Weapons Employment (U), Field Manual 101-31-2 (February 1963). (SECRET)*

[9] *Defense Nuclear Agency, Capabilities of Nuclear Weapons (U), (Part 1 of 2), Effects Manual Number 1 (July 1972). (SECRET RESTRICTED DATA)*

[10] *Defense Intelligence Agency, Physical Vulnerability Handbook--Nuclear Weapons (U), AP-550-1-2-INT (June 1969). (CONFIDENTIAL)*

**Material presented by Charles Sommers of BDM at a Defense Nuclear Agency briefing.*

The details of the two methodologies (AP-550 and dash two, as based on EM-1) are of concern here only insofar as they affect the nuclear damage assessment calculations, and this is the emphasis given to them. Details of their methodologies have been published.[5,9,10]

The drawbacks to EM-1 involve its inaccuracies at low yields and short ranges, cases that are likely to be of strong interest to tactical warfare games. The degree of damage is given by a series of damage categories and is less useful for sensitivity studies than a continuous scale. As an example, if the nuclear environment is slightly increased (as by mildly increasing weapon yield) and the corresponding increase in damage probability is insufficient to alter the resulting category of damage, the output of the code employing this methodology would remain unchanged. This despite the fact that the probability of damage has been increased! Specific drawbacks to the dash-two methodology (that employs EM-1) are that (1) the user cannot input other than stockpiled weapons to the computer codes that back up the manual, although these programs can be so modified on short notice; (2) it interpolates linearly between the effects of different weapon types, despite the fact that this is physically unfounded; and (3) due to the inability to vary the weapon yield or type, it is not a useful tool for war-game efforts or sensitivity studies.

The AP-550 methodology is based on the results obtained from 20-kT and 1-MT weapon yields--other yields require scaling from these values. The methodology is tied to one HOB criterion. But the most serious drawback--indeed, one that will render unsuitable any codes employing its use--is the concept of weapon radius. The output of AP-500 is a weapon radius that gives, for example, 50-percent probability of damage. Since he cannot determine the cause of damage, the user is unable to alter his input in order to modify the extent of the damage. Thus, sensitivity analyses are precluded, as well as proper use of vulnerability data, thereby confounding the determination of hardening fixes that help to prevent the occurrence of such damage.

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[5] *Department of the Army, Staff Officers' Field Manual, Nuclear Weapons Employment (U), Field Manual 101-31-2 (February 1963). (SECRET)*

[9] *Defense Nuclear Agency, Capabilities of Nuclear Weapons (U), (Part 1 of 2), Effects Manual Number 1 (July 1972). (SECRET RESTRICTED DATA)*

[10] *Defense Intelligence Agency, Physical Vulnerability Handbook--Nuclear Weapons (U), AP-550-1-2-INT (June 1969). (CONFIDENTIAL)*

7. SECOND-ROUND SELECTION

As described at the end of section 4, nine codes (table III) were found to have nuclear damage assessment routines that were identified as potentially useful both to needs of TNF/S and to the requirements of a flexible nuclear damage assessment code that could stand alone. The features of an ideal code were established in section 5 and they serve as a baseline against which to compare the nine candidate codes using the stringent selection criteria set forth in section 6. At this point in the analysis, the stringent selection criteria were applied to the nine codes to determine if one or more of these can be used "off the shelf" with suitable modifications, or if a new code must be developed.

The format for comparison of the codes is a matrix. The matrix uses the nuclear hit and nuclear kill categories and, specifically, the question areas of the survey questionnaire (table I). The nuclear hit comparison matrix is given in table VIII. The entries in the matrix use the following key:

+ indicates that the code in question has the capability required by that survey question area in sufficient detail to be appropriate to the needs of both TNF/S and the development of an independent nuclear damage assessment routine,

0 indicates that this capability can be input by the user, and

- indicates that the code does not properly address the question area and that the code in question would have to be modified (if this is possible) to adequately address this question area.

The individual "scores" of +, 0, or - within the matrix of table VIII were compiled from data gathered through telephone conversations and limited reviews of available documentation. Accordingly, although it is considered that these entries are reasonably accurate for providing relative comparisons and judgments, the entries do have "error bar widths" commensurate with their data sources.

The total "nuclear hit score" (+ has a "score" of 1, 0 has 0, - has -1) for each of the nine codes (and the ideal code as well) is given at the bottom of the matrix. From a nuclear hit point of view, the scores of Brigade Survivability and NUFAM are comparable to the score of the ideal code and are separated by quite a gap from the scores of the other codes.

TABLE VIII. NUCLEAR HIT COMPARISON MATRIX

	IDEAL	BRIG. SURV.	DOSDIS	DWEEPS	LADCAR	LANDEM	NONAME	NUFAM	TACNUC	TANDEM
<u>Target description</u>										
No. target elements, resolution	+	0	+	+	+	-	+	+	+	+
Size, shape, orientation	+	-	-	-	-	+	0	+	0	0
Personnel posture	+	+	+	+	+	+	+	+	+	+
Equipment types, posture, criticality	+	+	0	0	0	0	+	+	+	0
Communication links	+	+	-	-	-	-	-	+	-	0
Multiple targets	+	+	+	+	+	+	+	+	+	+
Associated errors	0	+	0	-	-	0	-	-	-	-
<u>Target location</u>										
Location and error	0	+	0	0	0	0	-	0	+	-
Movement vector	0	-	0	+	-	-	-	+	+	-
Detected element relation to target	+	0	-	-	-	-	-	+	-	-
<u>Weapon and its accuracy</u>										
Select DGZ	+	+	+	+	+	+	+	+	+	+
CEP	+	+	+	+	+	+	+	+	+	+
Reliability	+	+	0	-	-	-	-	+	-	+
Variability due to scenario	+	0	+	+	-	-	-	0	0	+
Range	+	+	+	-	-	+	-	+	+	+
Yield	+	+	+	+	+	+	+	+	0	+
HOB	+	+	+	0	+	+	+	+	+	+
Multiple weapons	+	+	+	+	+	+	0	+	+	-
HIT "SCORE"	15/18	11/18	7/18	3/18	0	3/18	0	14/18	7/18	5/18

Key: *+, code has this capability*
0, user can input this capability
-, code does not have this capability

The nuclear kill comparison matrix is presented in table IX and uses the same key as the nuclear hit comparison matrix in table VIII. The "total scores" from tables VIII and IX are presented at the bottom of the matrix. On the basis of the total score, Brigade Survivability is the only candidate code that shows strong promise. It also scored well in both the nuclear hit and kill categories.

TABLE IX. NUCLEAR KILL COMPARISON MATRIX

	IDEAL	BRIG SURV	DOSDIS	DWEEPS	LADCAR	LANDEM	NONAME	NUFAM	TACNUC	TANDEM
Environment										
Blast	+	+	+	+	+	+	+	+	+	-
Total dose	+	+	+	+	+	+	+	+	+	+
Neutron	+	+	+	-	-	+	+	-	-	+
Thermal	+	+	-	+	+	+	+	+	-	-
EMP	+	+	-	-	-	-	+	-	-	-
$\dot{Y}$	+	-	-	-	-	-	-	-	-	-
Reliable data source	+	EM-1	EM-1	EM-1	AP-550	AP-550	EXPERTS	AP-550	AP-550	AP-550
Flexibility	0	+	+	+	-	+	+	-	+	+
Weather, terrain	+	+	-	-	-	+	·	-	-	-
uncertainties	0	-	-	-	-	0	-	-	-	-
Personnel										
Data sources		EM-1	EM-1	EM-1	AP-550	NUA	EXPERTS	AP-550	AP-550	AP-550
Posture, flexibility	+	+	+	+	+	-	0	0	+	+
Time dependence	0	0	+	+	-	-	-	+	-	-
Blast	+	+	+	+	+	+	+	+	+	+
Total dose	+	+	+	+	+	+	+	+	+	+
Thermal	+	+	-	+	0	+	+	+	-	+
Equipment										
Blast	+	+	+	+	+	+	+	+	+	-
Total dose	+	0	-	-	0	+	0	+	-	-
Neutron	+	+	+	-	0	-	0	+	-	-
Thermal	+	-	-	-	0	+	+	+	-	-
EMP	+	+	-	-	-	-	0	-	-	-
$\dot{Y}$	+	-	-	-	-	-	-	-	-	-
Data source		EM-1	EM-1	EM-1	AP-550	AP-550	EXPERTS	AP-550	AP-550	AP-550
Level of damage	+	+	+	+	-	-	0	-	+	+
Time to repair	0	-	-	-	-	-	-	-	0	-
Mathematical approach										
Cookie cutter versus probabilistic	·	+	-	+	+	+	-	-	+	+
Monte Carlo, deterministic	+	+	+	+	+	+	+	-	+	+
Uncertainties treated	0	+	-	-	-	-	-	-	0	-
Edit capability	+	+	0	+	0	+	+	-	-	-
Meaningful output	+	+	+	+	+	+	+	+	+	0
"TOTAL KILL SCORE"	23/28	15/28	0/28	3/28	-2/28	6/28	6/28	-2/28	-3/28	-6/28
"TOTAL SCORE"	38/46	26/46	7/46	6/46	-2/46	9/46	6/46	12/46	4/46	-1/46

Key: +, code has this capability
0, user can input this capability
-, code does not have this capability

In addition to the nuclear hit and nuclear kill comparison matrices of tables VIII and IX, it is worthwhile to display alone the nuclear environments used in each code. These are shown in table X. A dot in the matrix indicates that the code in question does not possess the ability to calculate damage probability due to the indicated environment. From the entries in table X, it appears from the point of view of nuclear environments that Brigade Survivability, LADCAR, and LANDEM are first-rate codes.

TABLE X. NUCLEAR ENVIRONMENTS COMPARISON MATRIX*

Environment	BRIG. SURV.	DOSDIS	DWEEPS	LADCAR	LANDEM	NONAME	NUFAM	TACNUC	TANDEM
Blast									●**
Thermal		●	●					●	●**
Total dose			●						
Neutron			●	●			●	●	
EMP		●	●	●	●		●	●	●
γ	●	●	●	●	●	●	●	●	●

*An ● entry means the model does not have this capability
**Scientific Applications, Inc. is updating these environments.

Although the three matrices of tables VIII through X permit a category-by-category comparison of the codes, they do not indicate quantitatively just how appropriate a given code really is. To answer this question, the stringent selection criteria of section 6 are invoked at this point. The results of applying these criteria are presented as a matrix in table XI, the difficulty matrix. The categories that are numbered down the left side of the table correspond to the numbered categories in the stringent selection criteria table (table VII). An x in the matrix indicates a difficulty in a given category for a given code. A dot entry in the matrix indicates that the difficulty is sufficiently serious to warrant deleting the code from further consideration.

Of particular importance are the entries in category 11 for LADCAR, LANDEM, NUFAM, TACNUC, and TANDEM. These codes use the AP-550 methodology and, as discussed in section 6, codes using such methodology are deleted from further consideration since their outputs are not suitable for the performance of sensitivity studies.

The only major problem area associated with Brigade Survivability is that the code employs a weapons allocation routine, so that the user cannot choose the weapons laydown, an important capability for sensitivity studies. Presumably, this routine could be altered without excessive difficulty. The only major difficulty with DOSDIS is that it is not a government-available code; it is proprietary to Stanford Research Institute (SRI). The Scientific Applications, Inc. (SAI) code, NONAME, uses the same basic methodology as that employed by Brigade Survivability. As far as nuclear damage assessment is concerned,

TABLE XI. THE DIFFICULTY MATRIX

Difficulties in these categories†	BRIG. SURV.	DOSDIS	DWEEPS	LADCAR	LANDEM	NONAME	NUFAM	TACNUC	TANDEM
1									
2									
3								x	
4	x								●
5									●
6		x	x					x	x
7			x						
8			x	x			x	x	
9	x	x	x	x	x	x	x	x	x
10	x	x	x	x	x	x	x	x	x
11				●	●		●	●	●
12				x	x		x	x	
13	●	●				●	●		●

●, difficulty is sufficient to warrant deletion of code from further consideration
x, code has difficulty in this category
†See table VII for category descriptions.

NONAME can be regarded as the same as Brigade Survivability. It is, however, not available for use in its present form. The positive and negative attributes of all nine candidate codes are given in appendix C.

The intent of this survey was to minimize the need for a detailed technical investigation of the many existing tactical nuclear warfare codes by sorting out those of obvious (and not so obvious) nonrelevance to the needs of TNF/S. Accordingly, this selection of codes is indeed superficial from the technical point of view. Nevertheless, it reduced to three the number of codes that warrant detailed consideration (Brigade Survivability, DOSDIS, and DWEEPS). Basically, these three codes have the correct structure, but it is not now known whether they are internally correct, or even accurate, or whether they can handle the sensitivity studies currently envisioned for TNF/S.

At any rate, the survey indicates also that all three codes require substantial revisions before being acceptable for the needs of TNF/S and for use as a definitive nuclear damage assessment routine. Brigade Survivability must be modified to permit user-chosen laydowns that are not based upon "target value" as is specified now within the code. DOSDIS must be released from its proprietary position and must be modified to incorporate the thermal, EMP, and $\dot{\gamma}$ environments. DWEEPS must also incorporate the thermal (for equipment), EMP, and $\dot{\gamma}$ environments. The nuclear damage assessment routines in each of these codes must be modularized enough to be used independently of their respective parent codes.

8. DETAILS OF APPROPRIATE CODES

This section describes, in some detail, the three codes (Brigade Survivability, DOSDIS, and DWEEPS) that were ascertained in section 7 to be appropriate to the needs of TNF/S, as well as to possess the characteristics needed of an independent nuclear damage assessment routine. Details of the other six codes (sect. 4) that did not meet the stringent selection criteria of section 6 are given in appendix C. Briefer descriptions of all the codes encountered during the performance of this survey are listed in appendix A.

8.1 Brigade Survivability

A survivability model* was developed to expedite the determination of surviving assets and to provide a mechanism or basis for further evaluations. Within the model is a routine for surveying detailed damage to a deployed brigade or division in terms of target type, combat units, and functional areas affected by the nuclear attack as a function of time and nuclear resources, as well as a listing and description of the targets used in the study. The model results are presented in terms of an overview of the damage, including the fraction of the combat units damaged to specified levels by each type of weapon effect and the combat functional areas destroyed per combat phase.

The key elements or submodels of the combat system survivability model are the acquired target list model, the weapons allocation model, and the direct damage calculation model.

The acquired target list model operates on the available list of targets to determine the number of each type of target acquired. This selection of acquired targets is determined by estimates of the probability of target acquisition. A Monte Carlo technique is employed to specify which targets of a given type are required so that the expected damage to targets can be assessed as a function of time and retained for later use.

Weapons are allocated against the acquired list by use of the weapons allocation model, which can account for desired attack strategies and constraints on available weapons. The weapons are allocated according to target value and ability to kill each target by using a modified Lagrange Multiplier technique. Target value depends upon target importance or priority, ability to acquire each type of target, number of each type of target, and ability to kill each type of

Material presented by Charles Sommers of BDM at a Defense Nuclear Agency briefing.

target. Yields are based upon the strategy of either matching target vulnerability with the appropriate yield or achieving increased target damage against adjacent targets (bonus effects).

The damage calcuation model uses the designated burst point from the weapons aimpoint model and the warhead yield defined by the weapons allocation model to specify the damage to all targets near the burst point of the nuclear warhead.

Multiple targets are taken into account as point targets within the target acquisition portion of the code. The target can be resolved into 4-km by 4-km squares, with 20 subtargets possible per square. Target orientation cannot be specified. Five personnel postures can be input and personnel grids can overlap the equipment grids. Communication links are included by listing such specific items as radios. One can input errors in target location. The target allocation routine centers target centroids on those portions of the targets that are detected.

The weapons laydown routine allocates all weapons whose yields are chosen to match the target vulnerabilities in order to achieve a desired degree of damage. The programming avoids multiple kills. Weapon HOB, range, DGZ selection, CEP, and weapon reliability are all chosen by the routine.

The nuclear environments are taken from EM-1 and from discussions with field and laboratory workers. The environments include blast (even the terrain effects), total radiation dose, neutron fluence, thermal, and EMP (only for vertical antennas), but no $\dot{\gamma}$ effects. The effects of weather and terrain are included in calculating the thermal environment. There are no uncertainties associated with the environments calculations.

Personnel vulnerabilities include blast, total radiation dose, and thermal effects. Only immediate incapacitation is considered. Time dependence of personnel vulnerabilities is included only in a snapshot-by-snapshot manner. The code does calculate multiple dose effects and can group personnel casualties by dose and by cause.

Equipment is considered to be vulnerable to blast, neutron fluence, and EMP. Thermal and $\dot{\gamma}$ effects are not included. The three levels of damage are light, moderate, and severe. There is no account taken of time to repair.

The mathematical approach is based upon EM-1 and its scaling laws. It is probabilistic rather than cookie-cutter in that it uses adjustable confidence levels. It equates probability of kill with fractional coverage, which is invalid for small-yield weapons and low damage levels. There are extensive editing capabilities. This modular

code is not proprietary, was written in FORTRAN IV, and runs on a Control Data Corporation (CDC) 6400 computer. SAI's continual assessment of the code is, unfortunately, not independent since they created the code. The code is capable of calculating both direct and indirect losses.

8.2 DOSDIS

The DOSDIS[11] computer model, proprietary to SRI, was developed to estimate the prompt effects of nuclear bursts and to assess damage to military units and civilian population centers. It uses data presented in EM-1 to determine blast casualties for 10 personnel postures and to compute the neutron radiation dose, the secondary gamma-ray dose, and the fission-product gamma-ray dose received by survivors of blast effects and conventional weapons' fire. Immediate "ineffectives" and long-term fatalities due to radiation are estimated for a maximum human biological response. The model is designed for a two-sided multiple-burst attack, with military units either stationary or mobile. The model also provides the user with the option of including weapon CEP's to determine the AGZ of each weapon burst and the option of including CEP's to determine the actual location of each military unit or population center. These latter CEP's are input to account for target acquisition errors. A summary table provides an estimate of the total number of immediate ineffectives, long-term fatalities, and survivors by unit types or by countries.

The input consists of weapons laydown, resource data, maneuver data (when applicable), and functional titles for printout. The output categories are (1) individual weapon affecting each unit, (2) table indicating the distribution of survivors by the burst number for each unit in various prompt dose levels, and (3) the immediate ineffectives and the long-term fatalities and the long-term survivors by 20 minor functional categories (or alliances).

There are limitations to the inputs: 36,000 stationary units or 6000 maneuverable units, 1300 weapons, 99 weapon types, 10 personnel postures, 8 weapon warhead designs, 20 time frames, 0.01 to 10,000 kT weapon yield.

The computer used a CDC 6400, the language is FORTRAN IV, operating in a batch mode, with 70 K storage required. Two optional tape files and nine scratch files are needed for resource and weapon laydown. The time requirements are 5 s central processing units (CPU) time for processing 40 weapons against 50 maneuverable units. The code is unclassified.

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[11] *Stanford Research Institute, DOSDIS--A Computer Model to Estimate the Prompt Effects of Nuclear Bursts and to Assess Damage to Military Units and Civilian Population, SRI Project No. 90COV (April 1975).*

Multiple targets, up to about 400, all circular but of any size, are specified in the input. No further breakdown is possible, but these targets can be as small as squad size. The target locations are user specified, and the code can be modified to introduce target location error via the weapon CEP. Personnel are uniformly distributed in a target. Personnel grids, consisting of 10 postures, can overlap no more than two different equipment grids (e.g., tanks and jeeps), but personnel cannot be located within the target circles. Target orientation cannot be specified, nor can equipment criticality nor communication links. Target motion is included by programming and can accept up to 20 time frames. However, there can be no target motion during delay times.

Multiple weapons laydown can be specified. Multiple kill volumes are avoided. The weapon range HOB, DGZ, and CEP are input by the user. A slight modification of the code could be made to accept weapon reliability ("Monte Carlo'ed") as input.

Thermal, EMP, and $\dot{\gamma}$ effects are lacking (although slight changes in the code could alter $\dot{\gamma}$ inadequacies). Blast is calculated in detail, and neutron fluence is treated, as is total radiation dose. Their data source is EM-1. There are no weather or terrain effects, nor are uncertainties in the environments specified. The user can input specific changes in warhead design to alter gamma, neutron, or blast output.

Personnel vulnerability is the prime emphasis of the code and treats blast (overpressure and dynamic pressure) and total radiation dose. Thermal effects are lacking, but multiple dose exposures are included. The output cannot group casualties by dose.

In essence, the equipment vulnerability involves a cookie-cutter approach in that the damage is user specified and then a blast radius is calculated to give isodamage contours. Neutron fluence is also calculated for equipment damage but uses a probabilistic method. There is no equipment damage caused by thermal, EMP, or $\dot{\gamma}$ effects. There is no inclusion of time to repair equipment.

The weapons laydown involves a Monte Carlo approach for weapon CEP considerations, but no statistical analysis is performed as a result of this uncertainty. The code is proprietary to SRI and is made modular. No independent assessment of the code has been made. There is no target acquisition scheme tied to the code. One potentially useful aspect of the code is that the user can vary the calculation in a variety of steps from a purely probabilistic approach to that of a cookie cutter. The code has a chemical warfare module.

8.3 DWEEPS

DWEEPS[12] is a digital computer code for simulating the employment of tactical nuclear weapons (only) against a static or dynamic representation of ground forces and for assessing the resultant military casualties and damage and collateral civilian damage. The code has been used to investigate relationships among target intelligence capabilities, weapon system characteristics, employment doctrine, military effects, and collateral damage.

Two versions of the code have been developed: a version for a CDC-7600 computer using hard copy I/O and an interactive version for an XDS Sigma 7 computer with graphical I/O capability. Both codes are one-sided, Monte Carlo, and mixed deterministic and stochastic. Target intelligence is time stepped and weapons employment is event stepped in the CDC-7600 version. The graphical I/O version is time stepped. Both are currently dimensioned for 50 nuclear weapons, 1000 military units of any aggregation, and 1000 locations of civilians. The codes assess military and civilian casualties and damage resulting from prompt nuclear radiation, thermal radiaton, and blast. Multiple weapon effects and bonus military effects are considered.

Input consists of the military force data base, the civilian data base, target intelligence capabilities, and a weapon employment plan. Output consists of detailed and summarized assessments of military and civilian casualties and damage. The codes' limitations are that they are one-sided, are nuclear only, and do not consider terrain effects. EM-1 methodology is used.

Both versions require from a few days to a few weeks to prepare military and civilian data bases. Analysis of target intelligence and development of a weapon employment plan require 2 hr when using the CDC-7600 version, but only a few minutes on the Sigma 7. Employment of 20 weapons against a division-sized force requires about 1/2 min of CDC-7600 computer time. The same simulation can be performed on the Sigma 7 in about 15 min. This includes display of target intelligence, development of a weapon employment plan, simulated employment of the weapons, damage assessment, and display of the results. Analysis of the results requires from a few minutes to 2 hr, depending on the objectives of the user. The codes are unclassified without a data base and are used about 100 times per year. The technical contact is Robert P. Gard, University of California, Lawrence Livermore Laboratory, P.O. Box 808 L-95, Livermore, CA 94550.

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[12] *Lawrence Livermore Laboratory, DWEEPS: A Computer Code for Simulating the Employment of Tactical Nuclear Weapons (U), UCRL-51429 (July 1973). (SECRET RESTRICTED DATA)*

The target shapes are rectangles whose sizes are user chosen and located by latitude and longitude. Usually, company sizes are employed, although platoon-sized targets can be handled. The target orientation cannot be specified. The user chooses the number of target elements (and their resolution) that subdivides a given target into subareas of uniform value. The equipment grids can overlap those of the personnel and up to about 15 personnel shielding factors are available.

The code does not place "value" on the criticality of equipment. Communication links are not dealt with. The user is able to input target location uncertainties through weapon CEP and through probability of knowledge (POK) tables. Target motion is possible, making the code a dynamic one. Target acquisition has been modified in the past to account for detection of a target subelement that is not coincident with the target centroid.

The weapon yield is input by either yield menu or weapon-type menu. The weapon HOB is calculated once the DGZ and CEP are selected by the user. There is no ability to accept input concerning weapon reliability. The code does avoid multiple kill volumes in its output.

The nuclear environments include blast, thermal (but not for equipment), and total radiation dose (but not neutron fluence). No EMP or $\dot{\gamma}$ is included. No uncertainties in the nuclear environments can be input. The weather is taken to be solely that representing an average clear day.

Personnel vulnerability categories include blast, thermal, and total radiation dose. Casualties can be binned by dose in the output. The personnel postures (shielding) can be time dependent. Data are taken from the Army Nuclear Agency.

Equipment is only vulnerable to blast, and level of damage is in the EM-1 format. There is no consideration given to time to repair, despite the fact that the code is considered to be dynamic.

The mathematical approach is probabilistic, not cookie cutter. Monte Carlo techniques are used for the weapon delivery, target acquisition, and POK. However, no consideration is given to their statistical fluctuations. The program code is in FORTRAN IV.

The code is not proprietary and is in modular form. Parts of the code have been independently assessed by RDA. New vulnerability data can be input by the user as he receives them, and there is the ability to replay any situation using hindsight. The age of target intelligence is considered in the operation of the code.

9. CONCLUSIONS

The purpose of the survey reported here was to select a nuclear damage assessment routine for the Theater Nuclear Force/Survivability (TNF/S) program, coordinated by the U.S. Army Training and Doctrine Command's Systems Analysis Activity. A secondary goal served by the survey was to describe the current state of the art in nuclear damage assessment and to compare that with capabilities that could be readily developed.

In carrying out the survey, emphasis was placed on determining whether an existing code could be taken off the shelf to meet the needs of TNF/S. The procedure used to make this evaluation consisted of surveying the Govenment and private sectors to locate relevant codes and developing a survey questionnaire that permitted an evaluation of the detailed technical aspects of each code against an "ideal code." The attributes of the ideal code should adequately serve the needs of TNF/S,as well as the needs of any nuclear damage assessment routine that would be required for use in a larger war game or for use by itself.

The ability of the candidate codes to pass relevant selection criteria required of the ideal code served to identify appropriate codes. Three codes (Brigade Survivability, DOSDIS, and DWEEPS) were found to contain satisfactory nuclear damage calculation methodology. None of the three codes, however, is especially suitable for the needs of TNF/S.

For applications where one of these three codes is not appropriate, guidelines are presented for the flow scheme of a usable calculation routine that properly uses target vulnerability data and has meaningful output. Documentation is presented and referenced for all the codes considered in the survey in a degree of detail commensurate with their relevance. In addition to the flow scheme and features of the ideal code, a listing is presented of the positive attributes that might be desired of a code regarding its future application and coupling to other codes.

ACKNOWLEDGEMENTS

The author expresses his thanks to W. E. Sweeney, Jr. and J. V. Michalowicz for numerous and fruitful discussions concerning the survey and its progress.

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(2) U.S. Concepts Analysis Agency, Abstracts of Studies, Bethesda, MD (January 1976).

(3) Harry J. Walther, Catalog of War Gaming and Military Simulation Models, 6th ed., Studies, Analysis, and Gaming Agency (SAGA) 236-75 (June 1975), AD 012803.

(4) W. E. Sweeney, Jr., C. Moazed, and J. Wicklund, Nuclear Weapons Environments for Vulnerability Assessments to Support Tactical Nuclear Warfare Studies, Harry Diamond Laboratories TM-77-4 (June 1977).

(5) Department of the Army, Staff Officers' Field Manual, Nuclear Weapons Employment (U), Field Manual 101-31-2 (February 1963), a revision is in press. (SECRET)

(6) W. E. Sweeney, Jr., A Vulnerability Array for Tactical Nuclear Warfare Studies, Proceedings of the 37th MORS Symposium (Military Operations Research Society), Alexandria, VA (June 1976).

(7) W. L. Vault and W. E. Sweeney, Jr., The Vulnerability Data Array, American Defense Preparedness Association Vulnerability/Survivability Proceedings (October 1976).

(8) K. LePoer, EMP Survival Profiles for Tactical Equipment, American Defense Preparedness Association Vulnerability/Survivability Proceedings (October 1976).

(9) Defense Nuclear Agency, Capabilities of Nuclear Weapons (U), (Part 1 of 2), Effects Manual Number 1 (July 1972). (SECRET RESTRICTED DATA)

(10) Defense Intelligence Agency, Physical Vulnerability Handbook--Nuclear Weapons (U), AP-550-1-2-INT (June 1969). (CONFIDENTIAL)

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(11) Stanford Research Institute, DOSDIS--A Computer Model to Estimate the Prompt Effects of Nuclear Bursts and to Assess Damage to Military Units and Civilian Population, SRI Project No. 90COV (April 1975).

(12) Lawrence Livermore Laboratory, DWEEPS: A Computer Code for Simulating the Employment of Tactical Nuclear Weapons (U), UCRL-51429 (July 1973). (SECRET RESTRICTED DATA)

APPENDIX A.--SURVEYED CODES AND CONTACTS

This appendix provides listings and brief descriptions of the codes examined in the course of a survey of codes that employ nuclear damage assessment. The first listing is alphabetical, by code acronym; the second is by code originator. The information presented here was obtained through conversations with key technical personnel and through documentation. Whenever possible, these sources are cited.

ATLAS: a two-sided/deterministic model involving land and air forces at the division level, possibly capable of considering units as small as battalion.[1] It is dynamic in steps of 24 hr. It is a planner's war game. Output is FEBA (Forward Edge of the Battle Area) motion, based on ratios of opposing forces computed from firepower scores. It uses AP-550 methodology. It can accept NUFAM (see below) output as its input and may now be modified to accept nuclear inputs. The contact is the U.S. Concepts Analysis Agency, Bethesda, MD.

BARBAROSA: a scenario selection model that sets up threats and forces to which a damage assessment routine could then be applied. The contact is Richard Cook at Martin Marietta, Orlando, FL, 305-352-3284.

BRIGADE SURVIVABILITY: discussed in detail in sect. 8, body of report, and appendix C.

CASM: a model presently under development at Studies and Analysis Office, SAGA; completion is four years off. It will be a tactical, nuclear model, aggregated at the theater level and will use air and ground forces as well as C^3 (communications, command, and control). The contact is the Air Force Chief, Studies and Analysis Office, Studies, Analysis, and Gaming Agency (SAGA), Arlington, VA, 202-694-8013.

CATTS/MAFIA: CATTS is an interactive war-game program used for training troop commanders; MAFIA converts CATTS to nuclear form by converting howitzers to nuclear capability. It is aggregated at the company level, will not subdivide battalions, and uses EM-1 "cookie-cutter" methodology for prompt radiation. The contact is Cliff Peer, TRW Systems Group, Los Angeles, CA, 213-535-3620.

COMBAT II: a model that deals with air/ground combat, is aggregated at the company level and above, is designed to provide an overview of theater-level mixed combat exchanges, and has as output the time-dependent FEBA.[2] It is fast-running and useful for sensitivity

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[1] *"ATLAS: A Tactical, Logistical and Air Simulation": RAC-TP 338, AD 850355.*

[2] *Defense Nuclear Agency Report No. DNA 37?1F, BDM/W-75-173-TQ (August 1975).*

studies since it is a differential-equations-based code. It has no nuclear damage assessment scheme for tactical nuclear warfare use. The contact is John Bode, Braddock, Dunn, and McDonald, McLean, VA, 703-821-5000.

DACOMP: a model that applies the SEER III (see below) single-weapon fallout model to the analysis of full-scale strategic nuclear attacks.[3] It emphasizes the radiological fallout effects on population centers. The contact is Paul W. Wong, Stanford Research Institute, Menlo Park, CA 415-326-6200.

DCAPS: a model that selects single nuclear-weapon aimpoints to maximize target damage and minimize nontarget damage. It determines a lethal aimpoint region within which the primary target kill criteria are met and searches this region for desirable aimpoints based on user-supplied damage criteria. The contact is CPT John Anderson, Defense Nuclear Agency (VLWS), Washington, DC, 703-325-7403.

DEMS: a two-sided, division-sized, dynamic combat action model that has surface and air nuclear-delivery capabilities.[4] It considers a 12-hr time frame and its outputs are expenditures and costs.

DIVWAG: a model that performs firepower, mobility, target acquisition, and combat service support functions in a division level of aggregation for a two-sided, computer-assisted, analytical war game. The contact is COL T. DeShazo, U.S. Army Combined Arms Center, Combat Operations Analysis Directorate, Ft. Leavenworth, KS, 913-684-4008.

DOSDIS: discussed in detail in section 8, body of report, and appendix C.

DWEEPS: discussed in detail in section 8, body of report, and appendix C.

FORECAST II: a one-sided, nuclear, stochastic model involving land and air forces. It uses AP-550. It assesses collateral and structural damage to targets (bridges, buildings, etc.) collocated with the aimpoint. Th contact is COL Henkey, Concepts Analysis Agency, Bethesda, MD, [illegible] -295-1681.

JEREMIAH: a nonnuclear war-game model that is interactive via computer graphics. Artillery has just been included. The contact is Ken Froshner, Lawrence Livermore Laboratory, Livermore, CA.

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[3] *Defense Nuclear Agency, Utilization of the SEER Fallout Model in a Damage Assessment Computer Program (DACOMP), DNA 3608F (February 1975).*

[4] *Lockheed Missiles and Space Company, Dynamic Effectiveness Model Study (DEMS) (U), Sunnyvale, CA (November 1965), LMSC-B093632, -B093625, -B095288 (Vol. 4), DDC numbers 380079, 380080, 380081.*

LACOMP: the LASL version of DACOMP (see above) that has to be used with LANDEM (see below) to provide a nuclear effects code. LACOMP is a fall-out prediction model only.

LADCAR: discussed in detail in section 7, body of report, and appendix C.

LANDEM: discussed in detail in section 7, body of report, and appendix C.

LULEJIAN-I: a two-sided nonnuclear, thoater-level war-game model developed for the Weapon System Evaluation Group for making force assessments, force deployment studies, and associated trade-offs. The output is FEBA movement and attrition of weapon systems and personnel. The contact is Herbert Hoover, Lulejian & Associates, Torrence, CA, 213-542-5561.

MCNUKEM: a research tool for determining how to construct tactical nuclear models and sensitivity studies. It is static and undocumented. The nuclear calculations are consistent with the needs of a nuclear damage assessment scheme, but it employs AP-550 methodology for blast, thermal, and total dose. The contact is Morgan Grover, RDA, Santa Monica, CA, 213-822-1715.

MINTSIM: a model undergoing development to correct basic flaws and to increase the level of aggregation to theater level. This war game considers a multiweapon laydown against a multitarget array and includes target acquisition. The development is currently in a hold pattern until the Department of the Army provides guidance. The contact is Phil Lowry, Flow General Laboratories, McLean, VA, 703-893-5900.

NAR: a model to assess damage from a manually planned nuclear fire plan against intelligence-gathered targets. It is a part of NUFAM (see below).

NDAM: a strategic, one-sided, deterministic nuclear damage assessment model, currently being documented, that addresses the prompt radiation effects of a user-specified weapon laydown on an array of installations and personnel targets. The contact is Patsy McGrady, Defense Intelligence Agency, Washington, DC, 692-6373.

NONAME: essentially the Brigade Survivability nuclear damage assessment routine, plus peripherals. For details, see section 8, body of report, and appendix C.

NUC AMMORATES: a model that computes ammunition consumption rates and has evolved into a small-unit, static war game that has been recently updated to include nuclear capability.

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NUCWAL: a model that concerns nuclear weapons allocation, nuclear forces requirements, and blast damage assessment (by AP-550) to point and area targets in a strategic war. It addresses allocation of the nuclear stockpile in a general war and the determination of the size of the nuclear stockpile needed to inflict a predetermined level of damage in a one-sided deterministic game. The contact is Carroll Strom in the Pentagon, 202-695-2277. See also RADSUM.

NUDAS: a nuclear damage assessment routine that meets the requirements of the flow scheme of the ideal code (sect. 5, body of report), but only considers one weapon against one point or area target. All environments are included and vulnerability calculations are performed properly. It is an undocumented research tool at present. The contact is John A. Rosado, Harry Diamond Laboratories, Adelphi, MD, 202-394-3100.

NUFAM: discussed in detail in section 7, body of report, and appendix B.

QTEM: a nuclear, dynamic, red-on-blue (unfriendly force-on-friendly force) war-game model aggregated at the corps level; although much finer resolution is possible, it involves extensive work. It calculates damage to point and area military and civilian targets. Only troop deployment involves terrain. No weather control or communication-link vulnerabilities are included. The nuclear damage assessment routine is appropriate to the needs of TNF/S (see sect. 5, body of report), except that AP-550 methodology is used in some damage calculations. There are only three levels of equipment damage and six dose categories for personnel. Personnel postures can be time dependent. The choice of the weapon laydown can be based on the minimum or maximum target response desired or can be made by the user on the basis of weapons' yields. Environments exclude neutron fluence, $\dot{\gamma}$, and EMP. EM-1 methodology is followed. The code includes target acquisition time, decision time (to weapon laydown), and fire-planning coordination time. The contact is Norm Breazeal, Sandia Laboratories, 415-455-7011 X2733.

RADSUM: a static, strategic, lowly aggregated war game, yet it lacks equipment on the small scale. It is entirely based on AP-550 and is limited in environments that it can handle. Military value of equipment and personnel is involved. It is an undocumented code. The contact is Robert Green, Defense Communications Agency, the Pentagon, 202-695-2277.

RAM: a model that assigns artillery batteries to targets in accordance with red doctrine. It is nonnuclear. The contact is C. E. Van Albert, Concepts Analysis Agency, Bethesda, MD, 301-295-1696.

RAPIER: a model that assesses nuclear effects in producing civilian casualties within a geographic area limited[5] to 80 × 80 km. Populations are square gridded in yield-dependent sizes. Various shielding factors represent various occupations of buildings. It is a strategic code. The contact is Marvin Drake, Scientific Applications, Inc., LaJolla, CA, 714-459-0211.

SATAN III: a two-sided tactical, nuclear model that can aggregate as low as company size. It uses TANDEM (see below) as a subroutine for population damage. It involves land and air forces. The contact is Ralph Harris, Studies, Analysis, and Gaming Agency, Joint Chiefs of Staff Command and Control Center, the Pentagon, 202-695-3780.

SCORES: a map-exercise war game that uses classified scenarios. The nuclear excursion portion is capable of aggregating as low as company level but with much difficulty. It handles multiple weapons against multiple targets, but only addresses radiation damage, and that by a cookie-cutter approach. It includes terrain effects to the extent of troop deployment. The output answers two questions: Was the nuclear deployment adequate to end the conflict? How soon can blue regain its strength? The contact is COL Woodmansee, Training and Doctrine Command, Ft. Leavenworth, KS, Autovon 680-3164.

SEER III: a single nuclear-burst fallout model accepting weapon yields[6] in the range of 0.1 kT to 100 MT. Its outputs are dose and dose-rate patterns. The contact is Paul W. Wong, Stanford Research Institute, Menlo Park, Ca, 415-326-6200.

SIDAC: a model that accepts only strategic targets; it is not set up for battlefields or their scenarios. It employs AP-550. It is a modular one-sided war game, simulating land, air, and sea forces as well as civilian and paramilitary forces. Any level of aggregation is possible. Delayed radiation effects are included. The contact is Paul W. Wong, Stanford Research Institute, Menlo Park, CA, 415-326-6200, (see Defense Documentation Center AD 910-614L).

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[5] *Defense Nuclear Agency, An Evaluation of the Tactical Nuclear Damage Evaluation Model (TANDEM) (U), DNA Report No. DNA 3733F (July 1975). (SECRET).*

[6] *Defense Nuclear Agency, SEER II: A New Damage Assessment Fallout Model, DNA 3008F (May 1972). SEER III has not yet been documented.*

APPENDIX A

SNAP: a strategic nuclear model designed to optimize targets destroyed by blast (AP-550) using existing stockpiles. It will not deal with battlefield situations. It is basically a one-sided target-acquisition model. The contact is at the Pentagon, NMCSSC/B205, 202-695-2277.

SPHINX: a nuclear damage assessment scheme that can be applied against a target array of objects aggregated at the brigade level. It has been incorporated into NUFAM and SATAN III (see above). The contacts are the same as those for these two codes.

STANCE-78: a large war-game model that includes tactical, nuclear conflict between a U.S. corps and a Soviet tank army in allied central Europe.[7]

TACNUC: discussed in detail in section 7, body of report, and appendix C.

TAGS: a theater-level, nuclear, tactical war game that can be aggregated to as low as division level. It is a cookie-cutter model that includes time to repair equipment. Its output is troop and aircraft survival and FEBA motion at the corps level.

TALLEY/TOTEM: a nonnuclear artillery war code. The TALLEY portion deals with air combat, while the TOTEM portion deals with ground forces. The contact is Don Emerson, Rand Corporation, LaJolla, CA, 213-393-0411, X309.

TANDEM: detailed in section 7, body of report, and appendix C.

TARTARUS: a two-sided, deterministic model involving land forces, although close air support and nuclear weapons can be included.[8] It is aggregated at the battalion to division levels. The calculational procedure involves the solution of differential equations based on Lanchester's linear law. The contact is at the Concepts Analysis Agency, Bethesda, MD, 202-295-1630.

UNICORN: a conventional and nuclear-weapon optimum allocator model that aggregates forces at higher than the division level for tactical warfare. The nuclear package deals only with radiation and blast. The code can guarantee a least-cost allocation to achieve specified damage levels. It includes rate-of-fire limitations, target acquisition, tactical and strategic C^3, and weapon survivability estimates. The contact is the Office of the Secretary of Defense (Plans, Analysis and Evaluation), Strategic Programs at the Pentagon, 202-695-9180.

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[7] *Studies, Analysis, and Gaming Agency, Study Tactical Nuclear Conflict Central Europe - 1978 (Stance-78) (U), General Purpose Forces Division, Joint Chiefs of Staff, Washington, DC (June 1972) (TOP SECRET).*

[8] *TARTARUS IV N/COCO Players and Technical Manual, AD 829525L.*

UNNAMED LULEJIAN MODEL: a static, tactical nuclear code treating aggregates as low as battalion, including tubes and launch sites. Cookie-cutter methodology is used for prompt and delayed nuclear radiation due to total dose only (no EMP or $\dot{\gamma}$). The target acquisition routine is distance and weather sensitive. The contact is Herbert Hoover, Lulejian & Associates, Torrence, CA, 213-542-5561.

UNNAMED HEADQUARTERS EUCOM (European Command) MODEL: under development to provide tactical nuclear capabilities using DOSDIS (see above) as a subroutine.

The listing below is alphabetical by company or organization responsible for the codes listed.

BDM: COMBAT II
CAA (Concepts Analysis Agency): ATLAS, FORECAST II, NAR, NUFAM, RAM, SPHINX, TARTARUS
CAC (U.S. Army Combined Arms Center): DIVWAG
DCA (Defense Communications Agency): CASM, NUCWAL, RADSUM, SATAN III, SNAP, SPHINX, STANCE-78
DNA (Defense Nuclear Agency): DCAPS
DIA (Defense Intelligence Agency): NDAM
EUCOM (European Command) Headquarters: UNNAMED Model
Flow General: MINTSIM
GRC (General Research Corporation, Flow General): MINTSIM
HDL (Harry Diamond Laboratories): NUDAS
IDA (Institute for Defense Analyses): TACNUC
LASL (Los Alamos Scientific Laboratories): LACOMP, LADCAR, LANDEM
L^3 (Lawrence Livermore Laboratory): DWEEPS, JEREMIAH
Lockheed: DEMS
Lulejian & Associates: LULEJIAN-I, UNNAMED Lulejian Model
Martin Marietta: BARBAROSA
NMCSSC: see DCA, SAGA-JCS-CCTC
OSD-PA&E (Office of Secretary of Defense--Plans, Analysis and Evaluation): UNICORN
Rand: TALLEY/TOTEM
RDA: MCNUKEM
SAGA-JCS-CCTC (Studies, Analysis, and Gaming Agency - Joint Chiefs of Staff--Command and Control Technical Center) see DCA
SAI (Scientific Applications, Inc.): Brigade Survivability, NONAME, RAPIER, TANDEM
Sandia: QTEM
SRI (Stanford Research Institute): DACOMP, DOSDIS, SEER-III, SIDAC
TRASANA (U.S. Army Training and Doctrine Command, Systems Analysis Activity): SCORES
TRW: CATTS/MAFIA

APPENDIX B.--USEFUL ATTRIBUTES OF AN IDEAL CODE

This appendix provides a listing of the various positive attributes possessed by the codes examined in the course of this survey. Many of these attributes came from codes that were not deemed appropriate to the needs of the TNF/S Code. The primary and secondary attributes needed for that code are listed in section 5, in the body of the report. The primary attributes are those features that are needed, at the minimum, to perform nuclear damage assessment. The secondary attributes are those deemed necessary to enhance the current applicability of a code. Accordingly, the "tertiary" listing presented here should be regarded as consisting of attributes that are anticipated to be desirable in adequately performing war games of the future.

The input and output formats of the damage assessment routine, and indeed of the code in which it is used, must be compatible with the corresponding formats of codes involving: conventional weaponry, chemical and biological weaponry, strategic codes, scenario selection codes, fallout codes, air combat codes, ammunition comsumption codes, and codes that minimize collateral damage, in order to ensure that damage categories and criteria are consistent and that the codes couple to each other.

It would be possibly advantageous to have the future capability of coupling the code in question to a routine that optimizes the target damage, given as input a certain weapons supply.

Any code, present or future, that deals with nuclear damage assessment must contain a physically meaningful criterion for distinguishing between point and area targets. It must be capable of differently subdividing equipment targets and personnel targets if so desired, because one may be able to be treated as a point target whereas the other cannot.

The nuclear damage assessment routine should be able to flag obstacles created by a nuclear burst as they are created in order to properly specify target/troop motion that occurs thereafter.

The nuclear damage assessment routine must be able to account for changes in warhead design.

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It would be desirable to establish a matrix that stores redundant, calculated quantities, thus permitting simultaneous damage calculation runs (for sensitivity studies, etc.), thus reducing the number of parallel damage calculations.

It might be useful to have interactive graphics displays, or even to have a red man in the (calculational) loop confronted (via the displays) with a blue man in the loop.

In the tradition of the Brigade Survivability study, it is often useful to distinguish between direct and indirect losses. Also, the concept of time to repair (also cannibalization) must be incorporated, especially for personnel for long-lasting encounter times.

In the absence of proper target vulnerability data, perhaps the code could fall back upon FM-101-31 or AP-550 methodology. The output must be flagged accordingly.

It would be eventually useful tc involve a target acquisition scheme that includes weather, target distance, and target intelligence age dependences. Possibly one could Monte Carlo the point on the target that is detected relative to the location of the target centroid.

An eventual war-game code in which a nuclear damage assessment scheme is used would include air, ground, sea, and possibly exoatmospheric forces and red/blue asymmetry. It would be able to deal with arbitrary levels of aggregation and serve as a troop-commander training tool. The code could consider deployment policies and give the time dependence of the forward edge of the battle area (FEBA). In its ultimate form synergistic effects (e.g., weakening of a radio tower by the thermal environment from a nuclear burst preceding the associated blast) would be included, a step clearly beyond present-day capabilities.

APPENDIX C.--FIRST-ROUND-SELECTED CODES

This appendix presents the technical details of the nine codes that were found in section 4 (in the body of the report) from the first-round selection, to be appropriate to the needs of Theater Nuclear Force/Survivability (TNF/S) in the area of nuclear damage assessment. Appendix A lists the details of all the codes surveyed, but in a considerably less thorough fashion than is presented here. Section 8 of the body of the report gives the details (as thoroughly as for the codes in this appendix) of the three codes that were found to be relevant to the needs of TNF/S, that properly utilize vulnerability data, and whose methodology is useful for sensitivity studies.

Brigade Survivability: one of the three codes covered in detail in section 8.

DOSDIS: discussed in detail in section 8, body of report.

DWEEPS: discussed in detail in section 8, body of report.

LADCAR: basically a research tool; handles conceptual weapons. It performs warhead analysis to tailor a single weapon to defeat a single target in order to find the most appropriate warhead for the specified scenario. A typical run would treat one tank company and one burst and then input the output to a larger model.[1] The target is a circle that can be subdivided into subtargets of any resolution. The target cannot move, nor is there an associated target location error. The target is located by its distance from the burst, and the detected portion of the target is assumed to be its centroid. The internal distribution of target value is Gaussian over an R95 radius. There can only be one distribution of personnel and one shielding per circle. The user can input equipment by type, although its criticality and relevant communication links cannot be specified.

There are no weapon range considerations or weapon reliabilities. The nuclear environment for people is specified by a 26-integer array that includes blast, total radiation dose, and thermal, using AP-550 methodology. Neutron fluence, $\dot{\gamma}$, and EMP are not considered, but neutron fluence is considered for people. All three environments that are treated are enfolded to give one damage P_k value. Weather effects on thermal flux can be input, but terrain cannot. There is no treatment of uncertainties in the input.

[1] *T. Dowler, Los Alamos Scientific Laboratory, Computer Codes for Analyzing the Prompt Effects of Nuclear Weapons (U), Report LA-6244-MS (March 1976). (CONFIDENTIAL)*

APPENDIX C

Personnel vulnerability includes blast, neutron, and thermal considerations and uses an 8000-rad guideline for prompt incapacitation of military personnel. Civilian personnel are treated differently. There is no time evolution for each of the 26 postures. The code cannot handle multiple doses nor can it group casualties by dose. Equipment is vulnerable only to blast, although neutron and thermal environments could be handled once the user becomes familiar with the code. There is no consideration of the time-to-repair concept.

The code is probabilistic, not "cookie cutter" or Monte Carlo. The output can be edited by burst number. The computer is a Control Data Corporation 7600 and the language is FORTRAN. The code is available to government users and has been published by the Energy Research and Development Agency. The radiation transport equations and the blast treatment (but not thermal) have been extensively assessed. The key technical contact is T. W. Dowler at Los Alamos Scientific Laboratory (LASL), Los Alamos, NM, 505-667-4335.

LANDEM: in essence, a static LASL version of TANDEM (see below) and, when run with the fallout code LACOMP (a LASL version of DACOMP, see app A), gives a complete nuclear effects code. It specifies military and collateral personnel casualties. It can treat multiple weapons and targets. Targets are invariant simple geometric shapes that are based on known troop deployment. The target size can be as small as the sum of five tank crews, or down to company size. Personnel spacing is invariant and includes several postures. There are 15 equipment types overall, and there can be several hundred per division. Equipment criticality and communication links are not included. The only way to introduce target uncertainties is by weapon CEP or actual ground zero (AGZ). The user inputs either weapon yield or type, range, HOB, and CEP, but not reliability. The user selects the individual latitudes and longitudes of the weapon laydown. The code avoids multiple kill.

The sole nuclear environments are blast (same as TANDEM) and the resultant cratering. It uses its own detailed radiation transport code, but does not treat EMP or $\dot{\gamma}$. There are no weather or terrain considerations.

Personnel and equipment vulnerabilities are taken straight from AP-550. One cannot specify other than equal personnel postures at the most refined subtarget levels. Personnel are vulnerable to blast, total prompt radiation dose, and thermal. There are no cumulative dose effects from multiple bursts. Personnel casualties can be grouped by dose. Equipment is considered to be vulnerable to blast, total radiation dose, and thermal. The only level of damage is that of severe damage. Time to repair is not included.

The mathematical approach is probabalistic rather than cookie cutter and does not include Monte Carlo techniques. The computer used is a CDC 7600, with FORTRAN language. The code is proprietary to the Government and has not been independently assessed in its entirety, although submodules have been checked by other Government agencies. There is no documentation available. The key technical contact is T. W. Dowler, Los Alamos Scientific Laboratories, LASL, Los Alamos, NM, 505-667-4335.

NONAME: the submodule of the Brigade Survivability model that deals with nuclear damage assessment. The appropriate details are included with those of Brigade Survivability that are given in section 8 in the body of the report.

NUFAM: a dynamic, corps-level, two-sided, multiple-weapons-on-multiple-targets, nuclear exchange model based upon limited or unlimited warheads.[2] The output can be time-sequenced by the user to become dynamic. Rectangular targets can be resolved to as small as platoon size with input orientation and can have uniform internal distributions. There can be as many as 6000 units in each of 36 major target units, and personnel grids containing five postures can overlap the equipment grids. There can be arrays of one type of equipment per subunit that can include communication links, although the only way to specify equipment criticality is by input targeting priorities. Input data uncertainties are not dealt with. A target location error contains a CEP that is related to the age of the intelligence that identified the target. Target motion vectors are specified by either the time to vanish from sight (flee time) or by manual off-line updates.

Weapons cannot be fired in multiples. The user can choose from a weapons menu of up to 60 yield/HOB combinations. Multiple-kill volumes are avoided. The user specifies weapon designated ground zero (DGZ), and weapon CEP is calculated from the weapon type. Weapon reliability is statistical.

Blast, total radiation dose, and thermal environments are specified through damage radii taken from AP-550. No consideration is given to neutron fluence, $\dot{\gamma}$, EMP, terrain (except for troop deployment), or data uncertainties. Blast and thermal damage are found by a cookie-cutter technique, while the total radiation dose (also cookie cutter) is both prompt and delayed. There can be five time-independent personnel shielding postures. There are no cumulative dose considerations, nor is time repair included. The computer is a Univac 1108 Executive 8,

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[2] *MAJ L. G. Lehowicz et al, U.S. Army Concepts Analysis Agency, Tactical Nuclear Weapons Requirements Methodology (TANREM) (U), Phase II: Methodology Development, Appendix F: Nuclear Fire Planning and Assessment Model, Report CAA-SR-74-21. (December 1974).*

using FORTRAN and Assembler language. The code is modular, is not proprietary, and has not been independently assessed. The technical point of contact is Robert Howe, Concepts Analysis Agency, Bethesda, MD, 301-295-1681.

TACNUC: a static, theater-level, nuclear and conventional combat model that contains policies for weapons deployment.[3] It was to be upgraded to include chemical warfare (as well as other modifications) by late 1976. The code treats multiple weapons against multiple targets of up to division size. The user characterizes the target shape and size by a standard radius and centroid location. Target orientation can be included if the user alters the targets' vulnerabilities. Theater-sized units are banded into division-sized sectors, which can be subdivided into zones. Primary and collateral targets are treated separately and differently. The four personnel shieldings can vary from zone to zone, but are constant in any given zone and can overlap any of the various equipment grids. Communication links are not included, but equipment criticality is taken into consideration by specifying combat effectiveness through point or area (either uniform or log-normal) value. Target location error cannot be taken into consideration. Target motion is at the division level and includes terrain considerations.

The reserve limits on the variety of possible weapons is enforced, and a wide variety of employment policies is available. Multiple kill volumes are not always avoided. The weapon yield is determined from a user-specified casualty requirement. The weapon CEP is Gaussian, the HOB is input by the user, and the weapon DGZ and range are computer established; weapon reliability is not included.

The nuclear environments include only blast and total radiation dose, not neutron, thermal, $\dot{\gamma}$, or EMP. They follow the AP-550 format. There are no terrain or weather considerations.

Personnel are vulnerable to blast and total radiation dose (which is cumulative), not to thermal. Casualties can be grouped by dose. Equipment is vulnerable to blast but not to neutron, thermal, EMP, or $\dot{\gamma}$. Several levels of damage are included. The nuclear subroutine does not include the time-to-repair concept, but the main program does. The code is modular, is not proprietary, and has not been independently assessed. The output is the combat unit status at the corps level. The technical contact is Edward Kerlin, Institute for Defense Analysis, Arlington, VA, 703-558-1323.

[3] *E. P. Kerlin et al, Institute for Defense Analysis, IDA TACNUC Model: Theater-level Assessment of Conventional and Nuclear Combat. Volume II: Detailed Description, IDA Report R-2H (October 1975).*

TANDEM: a model designed to estimate nuclear effects in theater warfare.[4] It is being upgraded and refined by Defense Nuclear Agency (DNA) through Scientific Applications, Inc. in regard to damage calculation and vulnerability data. When upgrading is complete (estimated date is spring 1978), the user will have the option of using FM-101 methodology instead of updated AP-550 methodology. It considers the effects of a single weapon on multiple static targets. Targets are of 1500-m size if unoccupied and, if occupied, subdivided into either point or complex subtargets (down to platoon size) whose orientation cannot be specified. It cannot handle industrial targets but can set targeting priorities. The methodology is by AP-550. The code contains no way to deal with errors or communication links. Target subareas contain a uniform distribution of value. The user can input weapons by either yield or weapon type (thereby setting the CEP). Delivery systems (and their ranges) are handled through the weapons allocation routine. HOB is either optimum or surface. The user or a subroutine selects the DGZ. The user can select the weapon reliability.

The nuclear environment is straight from AP-550, yet only recent versions have handled blast effects. The data source is EM-1 parametric fits from eight weapon types and includes total dose and neutron fluence. It does not handle EMP or $\dot{\gamma}$. Thermal flux is currently included. There are no weather or terrain effects.

Personnel are vulnerable to blast, total radiation dose, and thermal, but the output cannot group casualties by dose. Equipment vulnerabilities are currently being updated to deal with blast and thermal. The user can input the time-to-repair concept or other such properties.

The methodology is EM-1, but uses AP-550 for a last resort if data are lacking. The computer is an IBM 360 and FORTRAN IV language is used in this modular, nonproprietary code that has not yet been independently assessed. The technical contact is Marvin Drake, Scientific Applications, Inc., La Jolla, CA, 714-459-0211; but the requestor must first go through the DNA Vulnerability Directorate.

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[4] *Marvin K. Drake, Scientific Applications, Inc. An Evaluation of the Tactical Nuclear Damage Evaluation Model (TANDEM) (U), (July 1975), Report Number DNA 3733F.*

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